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Experiments in climate governance – lessons from a systematic review of case studies in transition research

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Abstract

Experimentation has been proposed as one of the ways in which public policy can drive sustainability transitions, notably by creating or delimiting space for experimenting with innovative solutions to sustainability challenges. In this paper we report on a systematic review of articles published between 2009 and 2015 that have addressed experiments aiming either at understanding decarbonisation transitions or enhancing climate resilience. Using the case survey method, we find few empirical descriptions of real-world experiments in climate and energy contexts in the scholarly literature, being observed in only 25 articles containing 29 experiments. We discuss the objectives, outputs and outcomes of these experiments noting that explicit experimenting with climate policies could be identified only in 12 cases. Based on the results we suggest a definition of climate policy experiments and a typology of experiments for sustainability transitions that can be used to better understand the role of and learn more effectively from experiments in sustainability transitions.

Keywords
Policy innovation, experiment, experimentation, sustainability transitions, climate policy

1. Introduction

Experimental approaches to governance have recently received increasing attention in academic literature as a force that may change societies. It has been claimed that experimentation can challenge the status quo and enable the testing of policy innovations, technologies and services in a temporary space (Sanderson, 2002; Berkhout et al., 2010; Heilmann, 2008; Schot and Geels, 2008; McFadgen and Huitema, submitted). Experiments have certainly also received political attention in the discourse on the renewal of governance. One example is the Finnish Government Programme of 2015 that aspires to create a 'culture of experimentation' that promises to deliver an experimentation programme, extensive trials and several smaller experiments, systematic experimentation and a legal basis to make the arrangement of experiments easier (Government Programme, 2015). Another example is the UK Cabinet Office that has an open governance lab with an aim to experiment.

However, both academically and politically, the notion of experiments appears to be used in multiple denotations. There is much variety in the understandings of what constitutes an experiment and what types of experiments exist. Moreover, despite the growing interests in experimentation as a force for societal change, knowledge has yet remained scattered around numerous single studies. Normative and positive values are often subtly interwoven in analyses.

In the literature on sustainability transitions, experimentation is a key theme with experiments often seen as a way of establishing niches – fringe spaces for currently dominant technologies or alternatives to current methods of governance (e.g. Schot and Geels, 2008; Kemp et al., 2007; Berkhout et al., 2010; Franzeskaki et al., 2012). However, de Bruijne et al. (2010, p. 276) have argued that the literature on sustainability and governance of transitions is *"vague and ambiguous with regard to how experiments should be set up and managed in practice to contribute to transitions*". Furthermore, Bos and Brown (2012) have argued that the transitions literature has paid disproportionate attention to technical experimentation, and there is lack of literature addressing the dynamics of how governance experimentation unfolds. Kern and Howlett (2009) also point out that empirical studies of transition management have tended to focus rather narrowly on technically oriented experiments coupled with conservative funding criteria, favouring close to market and economically viable technological options. The literature on resilience and adaptive management (Holling, 1978; Walters, 1986) offer a different take on the need for experimentation by connecting it to the complexity of "social-ecological systems" and to ways of increasing understanding of the behaviour of systems to be managed. Elsewhere, experiments are broadcast as an ideal way to produce the evidence basis underpinning policy interventions (e.g. Sanderson, 2002).

There is an apparent variation in the understanding of what actually constitutes an experiment (particularly in governance). For example, Tassey (2014) sees experiments as offering some flexibility and the opportunity to test novel options in a limited scale and that the interventions are at least to some extent reversible, whereas Sabel and Zeitlin (2012) consider experimental governance to be about the revision of rule-making through a recursive review of implementation experience in different local contexts. Here we set out to systematically

explore, drawing on published works, what is actually referred to as experiments in the context of climate transition governance and what evidence is used to explore experimentation. In this we contribute to the gradually growing knowledge of the extent and outcomes of experiments (Bulkeley et al. 2014a on urban experiments; Verbong et al. 2010 on Indian biogas experiments, Nair and Howlett 2014 on policy experiments in the water sector).

In this paper, we review experiments conducted either as intended policy experiments or as research experiments with the aim to feed results into policymaking, with a focus on climate change. We consider descriptions published in academic literature and examine in what contexts they have been undertaken, what the authors perceive as an experiment, and what types of outcomes the experiments are reported to have generated. Our aim is to learn from previous, in particular empirical, research on experiments in the context of transition governance with a view to advance the study of this diverse phenomenon. Our main conceptual reference point is, therefore, the literature on sustainability transitions, and how experiments can contribute to low carbon or climate resilience transitions. We base our discussion on a systematic review (Petticrew and Roberts, 2006) of experiments reported in published peer-reviewed journal articles.

One of our aims is to derive a typology of experiments and for that we specifically ask:

- What is the nature and focus of experiments that link sustainability transitions to climate governance;
- What kind of outputs and outcomes do these experiments generate; and
- What is their specific role in low carbon or climate resilience transitions?

We are particularly interested in identifying *policy* experiments that may contribute to transitions, as this is an angle largely missing in the previous transition literature (e.g. Bos et al., 2013). Heilmann (2008, p.2) stresses that policy experimentation refers to interventions done in a deliberate way, allowing for systematic learning. In our review we have taken into account both systematic experiments with policies and experiments that challenge or question existing policies.

In the following, we first discuss the literature on experiments in the context of transitions and policy innovation in Section 2. The research approach and the case survey method are explained in Section 3, and Section 4 presents the findings of the case study review. Section 5 discusses the findings, and Section 6 concludes the paper.

2. Background and theory on policy innovation and transition experiments

2.1. Policy experiments for climate policy innovation or vice versa

Jordan and Huitema (2014a, p.721) argue that, in academic literature, “too often, [policy innovation] appears as a rather blunt category – an undifferentiated form of ‘policy change’ – which robs it of explanatory value”. Policy experimentation is often used interchangeably with policy innovation (e.g. Strumpfh, 2002; Shlalensee and Stavins, 2012), without clarifying

either concept. Linking experimentation to policy innovation is important, as "[f]acilitating politically acceptable form of climate policy innovation (CPI) is increasingly urgent" (Upham et al., 2014) and, therefore, potentially an important output of experimentation. Jordan and Huitema (2014a, 2014b) have guided a body of work focussed specifically on policy innovation, and define policy innovation as (significant) novelty related to the emergence of a new policy, its diffusion and effects. In contrast, many definitions of policy experiments focus more on the temporal or reflexive characteristics of experimenting than on novelty.

Policy innovation can be depicted as a rather broad concept referring to novelty in both policy processes and their outputs (Jordan and Huitema, 2014a; Upham et al., 2014). This means that (1) policy innovation as a process change may, for example, link to increased flexibility for policy, encouraging substance related experimentation, or (2) policy experiments can lead to or refine policy innovations as an output. These outputs can be new policy goals, new policy instruments, or new types of leverage mechanisms or implementing organisations (Jordan and Huitema, 2014a; Upham et al., 2014). For example, a series of experiments prepared the ground for adopting the European emission trading scheme (Hildén 2014). Policy experimentation may also have the specific purpose of producing imaginative solutions and policy innovation (Greenberg and Robins, 1986; Heilmann, 2008).
In this paper we do not only look at (public) policy experiments but also broader 'governance' experiments carried out with potential implications on climate change mitigation or adaptation. This means that these broader configurations of experiments may include technological, social or political/policy novelties in different combinations – some resonating directly with the concept of policy innovation while others not.

The transitions perspective is interesting for both policy innovation and experiments, as Upham et al. (2014, p. 779) argue that while many (sectoral) policy innovations occur at the regime level, "the niche level can be depicted as consisting of small platforms for [climate policy innovation] CPI, with new technologies and solutions making new policies possible through demonstrating or testing policy inventions and innovation at small scales…"

2.2 Experiments in the sustainability transitions literature

The literature on sustainability transitions deals with how socio-technical systems can transform over time to more environmentally sustainable forms in a way that radical changes occur not only in technology but also in institutions, practices and culture surrounding the previously dominant technology (e.g. Markard et al., 2012). In the transitions literature, experiments have been defined as:

- "*planned initiatives that embody a highly novel socio-technical configuration likely to lead to substantial (environmental) sustainability gains"* and "*represent small initiatives in which the earliest stages of a process of socio-technical learning takes place…* [and] *typically bring together new networks of actors with knowledge, capabilities and resources, cooperating in a process of learning"* (Berkhout et al., 2010, p.262)"

Experimentation plays an important role in two different settings: (1) Experimentation as part of (bottom up) niche innovation, and (2) experimentation specifically initiated at a regime-level.

Regarding the niche innovations (1), the multilevel perspective (MLP) on transitions conceptualises transition dynamics occurring through interaction between three different levels: the landscape, the socio-technical regime, and niches (e.g. Geels, 2005, 2011; Smith et al., 2010). Innovation activities are considered to occur at the niche level that is associated with radical novelties and real-world experimental projects (e.g. Schot and Geels, 2008). An associated literature on strategic niche management (SNM) has emerged with an idea to support the development of (socio-)technological niches through experimentation-oriented policy tools (e.g. Hoogma et al., 2002). SNM sees "niche experiments as a compass for guiding future regime transitions in sustainable directions" with social learning through participative and iterative experimentation also in governance (Smith, 2006).

The regime level is of importance to experiments as it can both enable and hinder them, for example, depending on the way current institutions and policies or culture are oriented towards experiments (e.g. Schot and Geels, 2008). The socio-technical regime is seen as a rather persistent deep structure interlinking dominant technologies, infrastructures and formal and cognitive rules to existing networks of actors and prevailing practices, beliefs and habits (e.g. Geels, 2011). Experiments are by definition uncertain. There is a need, therefore, for a protected space or a special institutional set up against the mainstream regime that makes it possible to conduct experiments (Kemp et al., 2001; Berkhout et al. 2010). For example, cities can create incentives for the use of electric vehicles by developing protected spaces, such as differing parking tariffs or charging infrastructure, even when the internal combustion engine still has an overall competitive advantage (e.g. Temmes et al., 2014). Landscape comprises the exogenous environment beyond niche or regime influence (Geels and Schot, 2007), involving macro-economic, macro-political and cultural forces, patterns and development trends creating pressure for changing socio
-technical regimes.

Experiments initiated at a regime level (2) can be connected to a literature dealing with the purposeful management of transitions: transition management (TM). TM is a particular normatively oriented strand of the transitions literature. It differs from STM by highlighting the importance of visioning before engaging in experimenting, thus, making experimenting more coordinated than STM that emphasises 'free' experimenting (e.g. Schot and Geels, 2008). TM sees that transition experiments *"may be initiated by the transition arena network as an outcome of the transition agenda...* [and] *focus (among other things) on new institutional arrangements that can enable new pathways or innovations benefiting sustainability."* (Frantzeskaki et al., 2012, p.31).

The idea of TM is to facilitate radical change towards more sustainable systems of production and consumption through carefully designed processes that include four sets of operational activities: the strategic transition arena (problem structuring and vision development), tactical transition coalitions and networks (agenda building, transition paths), operational-level *experiments* and projects, and the monitoring and evaluation of progress (both in terms

of process as well as content), leading to further refinement (Kemp et al., 2007). TM aims for a portfolio of transition experiments that significantly contribute to sustainability objectives, connect a range of actors not typically involved in long-term strategy development, and produce social learning as a result (Grin et al., 2010).

The in-built reflexivity of TM (cf. Voss et al., 2009) is expected to create space for experiments that facilitate the transition, even if transition arenas as such do not (necessarily) have the formal powers of (mainstream) policy developers. Frantzeskaki et al. (2012, p.31) argue that "t*ransition experiments can be employed by* [mainstream] *policy developers to test new innovations (social innovations, institutional innovations or technological innovations)",* who thereby obtain evidence for the effectiveness of new ideas that can be adopted by mainstream policy. Transition experiments are expected to create outcomes through three different mechanisms: *"deepening (learning as much as possible from the transition experiment), broadening (repeating an experiment in an adjusted form in a different context) and scaling-up (embedding an experiment in the existing structures of the incumbent regime)"* (Grin et al., 2010, p.146). The extent to which they have done this is not well known as TM experiments have so far received little explicit empirical attention in the literature. Bos et al., (2013: p. 398) argue that TM "*fails to describe specific design and organisational characteristics of experimentation*". Porter et al. (2015, p. 526) also note that *"[l]ittle […] has been published on the analysis of real-world examples of experiments, and on the validity of […] design criteria for experiments in the governance of societal transitions.*"

3. Approach and methods

Our systematic review (cf. Petticrew and Roberts, 2006) targeted scholarly articles identified through Scopus. To capture the most recent debate we focused on studies published since 2009 in social sciences and humanities. For replicability through ease of access, conference papers and book chapters were excluded from the analysis. This meant that our review missed some empirical evidence reported in books or grey literature but, by using a wide range of scholarly literature, we were able to obtain a diverse set of studies on experiments. Other exclusion criteria concerned randomised control trials, as we focused on qualitative descriptions of real-world experiments. The caveat of such uncontrolled studies is susceptibility to bias (Petticrew and Robers, 2006) but they were used in order to get deeper insights into the study of experiments not provided by controlled studies.

"Experiment*" (with * indicating truncation to cover all variants) was used as a key search word, i.e. we excluded all articles that did not refer to experiment(s) or experimenting explicitly.[1] The other search words used were selected to link to climate change policy and governance by including terms such as "energy efficiency", "low energy", "energy saving", "renewable energy", "mobility", "transport", "adaptation" and "transition" (see Appendix 1). While the number of hits was 174 in total, based on twelve different search word combinations, the

[1] While we acknowledge that terms, such as 'pilots', could be used to describe a similar phenomenon as experiments, the purpose here was specifically to review research on experiments in order to analyse its current status.

content analysis of abstracts revealed that a large number of articles dealt with experiment as research design and not as a topic of inquiry. These articles were excluded from further analysis.

Through content analysis of abstracts, we identified in total 25 scientific articles that merited full-paper content analysis. Of these, 18 articles contained qualitative descriptions of 29 experiments that we scrutinized in the review. We included experiments that spanned from specific climate change mitigation or adaptation actions to broader objectives integrating climate issues. We also included seven articles that did either not contain an actual experiment or presented aggregated results of such a large number of cases that a detailed analysis was impossible. These articles were reviewed more generally in terms of how they defined experiments and what literature and sectors they referred to.

The identified core papers were explored using approaches from case survey (Lucas, 1974) and systematic review (Petticrew and Roberts, 2006) with the purpose of bringing diverse case studies together under a common conceptual framework. The case survey method allowed a systematic and structured synthesis of *'previous case-based research, drawing on the richness of the case material, on different researchers and research designs…'* (Newig and Fritsch, 2009: 2), while we were aware of the risk of bias in summarising uncontrolled studies (cf. Petticrew and Roberts, 2006). The analysis was structured following the components of policy evaluation (inputs, outputs, outcomes, target group, process) (Vedung, 1997). Our unit of analysis was the experiment rather than the scholarly article, meaning that an article describing several experiments provided several units for the analysis.

We carried out a qualitative analysis of the experiment descriptions to provide answers to pre-set categories that both described the nature of the experiment and evaluated it according to a number of criteria (Table 1). We selected the categories on the basis of our previous knowledge of experiments and socio-technical transitions as well as drawing on policy evaluation literature (e.g. Vedung, 1997). New categories were added inductively, when the analysis of the articles revealed missing but possibly important categories. We used componential analysis in the case survey, i.e. a systematic search for attributes (components of meaning) associated with the experiments (Onwuegbuzie et al., 2012). To achieve this we constructed matrices describing the experiments to identify the differences among the subcomponents of the categories (Table 1). Some of the codes (Section 2 in Table 1) were taken directly from those used by Castan Broto and Bulkeley (2013).

Table 1. Analytical categories for the case survey of experiments

Pre-set categories for case survey of experiments	
Main categories	Subcomponents
1. General categories providing background information	1.1 Definition of experiment used 1.2 Related theory/literature 1.3 Engagement of author with the experiment process
2. Categories adapted from Castan Broto and Bulkeley, 2013	2.1 Sector and focus of experiment (e.g. transport, energy, adaptation, built environment) 2.2 Technological innovation / social innovation / policy innovation (yes or no) [due to interest of this paper 'policy innovation' added compared to the original source]
3. Empirical detail on the experiments	3.1 Type of experiment (as described by the authors of the case study articles) 3.2 Objectives of the experiment 3.3 Climate objective / sustainability objective (yes or no) 3.4 Geographical location and scale 3.5 Duration of the experiment 3.6 Actors leading the experiment
4. Categories based on evaluation research (Vedung, 1997)	4.1 Inputs to the experiment (e.g. financial and human resources) 4.2 Process (how experiment unfolds) 4.3 Target actors of the experiment 4.4 Outputs/outcomes (realised) 4.5 Evaluation(s) carried out
5. Governance elements of the experiment	5.1. Link to governance (how presented in the article) 5.2. Local/city government involved / national government involved (yes or no)
6. Transition elements of the experiment	6.1 Upscaling or transfer potential 6.2 Learning processes 6.3 Incremental vs. systemic change 6.4 Drivers and triggering activities for initiating the experiment 6.5 Reversibility and decision points after the experiment 6.6 Level and nature of risk taking (financial and political)
7. Outcomes of the experiments	7.1 Policy and institutional change / new market or market change / new business practices / changed consumer or community practices / new technology / built environment and infrastructural change / change discourse (yes or no)

Subsequently, we identified typologies based on repeated instances in each category. In addition, the broader set of papers that did not include empirical descriptions of experiments was reviewed place the findings in a wider context. Investigator triangulation was used in that 2-3 people coded each article independently, and subsequently the first author merged the results. Differences in coding was treated as a reflection of uncertainty in the findings.

4. Results

4.1. Overview of experiments

Out of the 25 reviewed articles, 19 made some connection to socio-technical transitions theories. Out of 29 experiments, 22 were connected to transitions, five engaging particularly with TM and seven referring to socio-technical or sustainability experiments in the context of

SNM (Figure 1). The non-transition experiments contained three strategic spatial planning experiments and four experiments focusing on urban development. Only one of the experiments was described by the authors as a "governance experiment", although many were related to public policy or governance. Of the more generic articles Deitchman (2014) focused on policy experiments, whereas Stewart (2012) mentioned experiments as a complementary form of governance to traditional regulatory and fiscal measures.

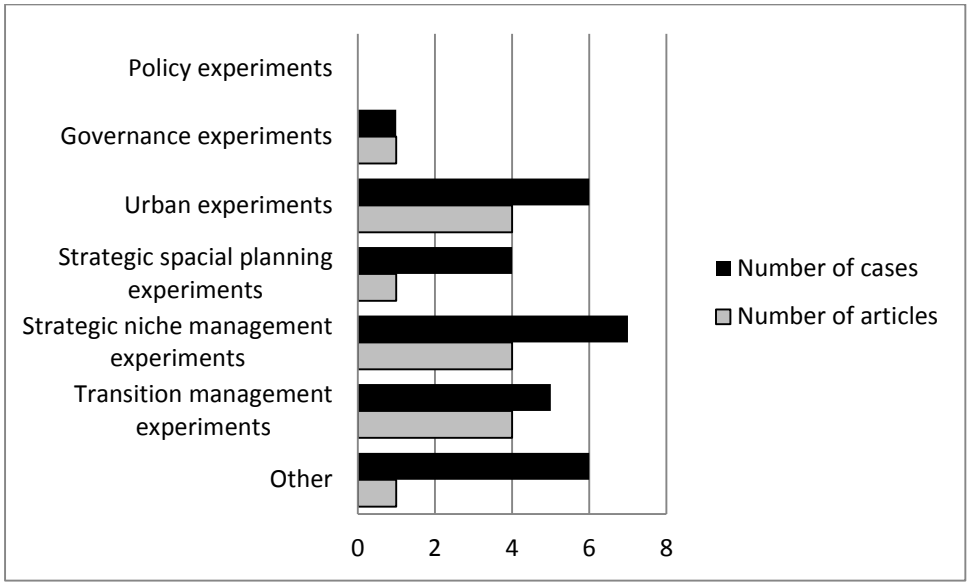

Figure 1. Summary of the types of experiments mentioned in the articles

In terms of empirical content, the sectors covered included the built environment, energy, transport, water, and community development (Figure 2). The experiments related to the built environment ranged from stimulating new housing and construction (e.g. Holm et al., 2011) to energy efficiency retrofits (Bulkeley et al., 2014b). Many cases crossed between the built environment and energy sectors or were even broader. Eighteen case studies were based in Europe (Belgium, Denmark, Netherlands, the UK, Finland, and Slovenia), six in Asia (India), two in Australia, two in Africa (South Africa) and one in South America (Brazil). Local government involvement was present in all but two cases, while the national government was somehow involved in only ten cases. There was a great variety in the leading actors behind the experiment, ranging from the public sector (municipalities, regional administration, and environmental ministry) to researchers, companies, entrepreneurs and independent groups. The cases analysed are summarised in Appendix 2.

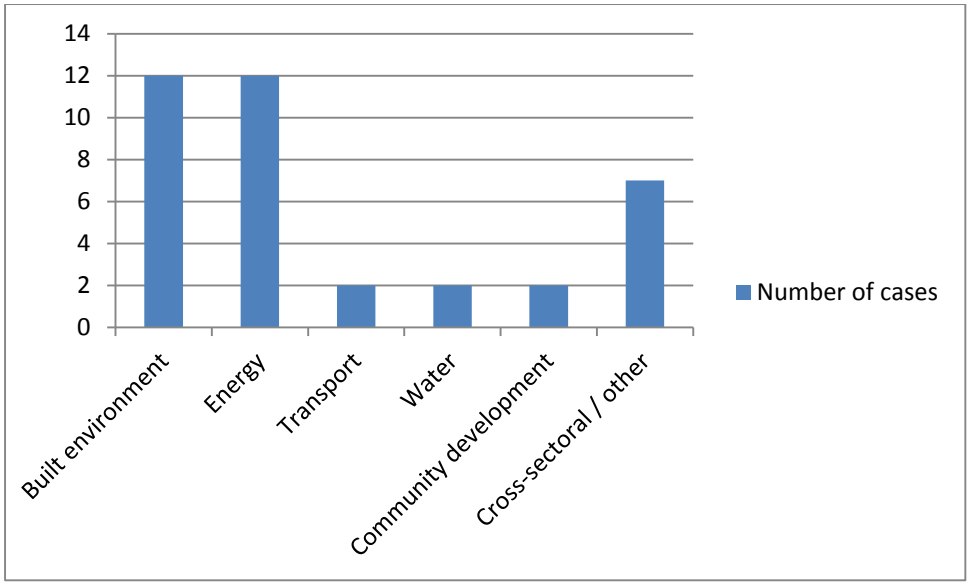

Figure 2: Sector focus of the experiment cases

Technological innovation was in focus in about half of the cases. An element of social innovation was present in 80% of the experiments, eleven cases integrating both social and technological innovation. While there were many similarities between the experiments in general, including a predominantly local or regional focus and the inclusion of elements towards social change, the experiments still presented a very wide range of processes. Their aims ranged from technology piloting and new market creation to creating sustainable visions and community engagement. In two cases, aims to experiment in low carbon were also connected to social housing objectives.

4.2 Policy innovation in the experiments

An element of policy innovation was detected in twelve cases; three of these were associated with transition management. In most of the twelve articles, policy innovation remained implicit, with the exception of Bos et al. (2013) and Bos and Brown (2014). This suggests that the role of experiments in the context of policy and governance innovation for societal transitions needs to be explored further.

In the Transition Arena Parkstad Limburg the policy experiment was based the idea that actors outside the regular administrative network could form a social vision that would steer the new master plan for the region (van Buuren and Loorbach, 2009). Another case reported by van Buuren and Loorbach (2009) was a pilot project, “an experiment garden” that similarly to the transition arena approach had a core group operating outside the administrative network but with frequent contacts to the administration in drafting an environmental impact statement for the municipality and developing practical innovations. Both of these can be seen as policy experiments for (local) engagement and empowerment that do not challenge existing regimes but may generate new learning. In Finland, a governance experiment involved bringing small municipalities outside the main cities together to act as “change laboratories” in seeking for new solutions to climate change mitigation with co-benefits such as job creation (Heiskanen et al. 2015). This can be seen both as an experiment for local engagement

and empowerment within the existing regime as well as an innovative way to connect local activities, support small municipalities in climate governance, and transfer lessons learned (broadening).

The development of urban energy in London (Bulkeley et al., 2014a), in contrast, built on the active involvement of the Mayor and the city administration in aligning institutions, techniques and artefacts around low-carbon and decentralised energy provision, resulting in specific experiments with novel solutions such as energy service companies aiming for energy saving and production using renewable sources (photovoltaics). The policy experiment tested new ways to set transformative economic processes in motion and could potentially lead to greater change.

Those experiments that establish new networks or bring in new actors can be seen to include elements of policy innovation. For example, Stenløse Syd District Planning with Ecorequirements in Denmark focused on one district, experimenting how a set of advanced eco- and energy-requirements for new buildings within district area planning could influence the building sector and the market. By becoming a showcase for 'conventional families' of the potential in normal but sustainable dwellings (Holm et al., 2011), it could disrupt housing and housing policies in the long run. The State of Sao Paolo in Brazil experimented with introducing solar heated water systems in social housing by new contractual terms for reference and procurement, resulting in market creation for and diffusion of new technology (Bulkeley et al. 2014b). Yet another approach was to focus heavily on empowering. Municipalities around Sydney, Australia, experimented with household-targeting series of workshops as a policy measure that led to a range of new skills for inhabitants as well as a modest new "political space" among the participating municipalities (McGuirk et al., 2015).

The examples reviewed largely present local, municipal-level policy experimenting as opposed to the national level. Stewart (2012, p. 338) has argued that innovative experimentation is "*more feasible at regional rather than at national or international levels because the scale is manageable yet significant resources can be leveraged*". It may also be that the scientific literature on transitions is biased, because it is easier to analyse and report on local and regional experiments than national or international climate experiments. Olesen and Richardson (2012) have addressed the interface of national and regional policy making in three cases of strategic spatial planning experiments. These experiments could be labelled as failures in terms of leading to a return of top-down control in spatial planning and not delivering desired outcomes, while still being useful by providing new learning through broadening.

4.3. Outcomes of experiments

In evaluating the experiments we focused on seven types of outcomes (Table 2). Three of these strongly focused on learning (changed discourse, policy and institutional change, and changed consumer or citizen practices), whereas the four other types are examples of different substantive outcomes that also include elements of learning to varying degrees. The outcomes also link to the ideas deepening (shifts in ways of thinking and practices and organising physical, economic and institutional structures), broadening (repeating experiments in different contexts and linking to other domains) and scaling up (embedding an experiment in established ways of thinking, doing and organising) (Grin et al., 2010). We evaluated the occurrence of a particular outcome as it was described in the source article(s) and our method of investigator triangulation revealed that there was some uncertainty in whether a particular outcome had been achieved or not (Table 2).

Between 70-90 percent of the reviewed experiments contributed to learning in the form of changed discourse and about 45-60 percent in policy and institutional change. Learning demonstrated through changed consumer or citizen practiced seemed much rarer, evident in circa 30 percent of the experiment descriptions. It is not possible to determine the disruptive force of the changed discourse alone as the studies tend to cover too short time periods. Those experiments that have resulted in policy and institutional change appear to have been able to affect the regime to some degree. Certainly deepening and broadening have taken place through experimenting. This does not, however, mean that they succeeded in disrupting the existing regime. The impact may in many cases be modest or incremental.

A number of experiments reviewed had resulted in substantive changes in technology, built environment, or business in an environmentally (or climate) friendly direction. New technology, and changed built environment and infrastructure were identified as outcomes in more than half of the experiments. They were also fairly unambiguous, as the proportion of uncertain observations was less than 30 percent. Changed business practices and market creation were also observed, but more than half of the observations were uncertain, suggesting that the interpretation of such impacts is more difficult. Although new business models were associated with new technologies it was often too early to tell, whether the business model leads to market disruption.

Table 2: Types of change that the experiments generated (n=29)

Type of change	No. of cases observed	No. of cases with uncertain outcome	Description
Changed discourse	20	7	Demonstrated often as a new shared vision (for the region or for solving a problem) or a shift in the shared vision; coming together to create future narratives with a more positive tone; integrating previously detached discourses; internalising a new way of thinking. In some case one of the few results was discourse, i.e. the experiment acting (purely) as a rhetorical device, while in another case changed discourse was also found to lead to improved cognitive understanding.
New technology	17	4	Diffusion of new energy technologies, including PV, solar water heating, various other building heating systems, biogas and ceiling insulation; creation of new technological solutions for building energy efficient and passive houses and sustainable roofs; a bicycle taxi and a metering device.
Built environment or infrastructure change	15	4	Land use planning changes with respect to energy efficient housing and town planning, station proximity to services, and water management. Building of low carbon infrastructure. Often operating at the district level as a test case.
Policy and institutional change	13	5	While often a result of the experiment, in some cases the policy experiment itself constituted as change. Some experiments were described to have led to "a new political space" or "new governance rules and practices". The changes included new spatial and district planning practices for enhancing eco-efficient and energy-efficient construction, renovation, transport, and water management; regionalisation of previously local policymaking; using local, outside actors in municipal or regional policymaking (often using the transition management approach),and the development of the role of the public actors.
New business practices	12	7	Novel business models for transport and renewable energy, in the latter case often combining product and service (maintenance). Changing business practices for farmers to maintain local environmental conditions. In London the ESCO promoted businesses based on alternative technologies and infrastructure networks. In the Finnish case, the increase in new jobs as a result was also described.
New market or market change	8	7	Market for energy efficient social housing; maintenance and development of solar PV and biomass extraction markets.
New consumer/citizen practices	8	1	Increased citizen engagement in local communities as operators and providers of solutions and services; alternative communities diverting from mainstream; and altered energy (technology) consumption practices. Energy saving as a way to reduce economic hardship.

While most experiments appeared to have fostered the wider objectives they were expected to advance, some had had the opposite effect. Some of the 'experiments' presented a return to more traditional policy approaches (that at least the authors viewed as negative) or experienced sub-optimal solutions or non-sustainably operated technology over the course of time, particularly evident in the Indian bioenergy heating experiments that had been followed up during several years after initiation.

For many experiments, academic analysis had occurred so close to its realisation that no definite results on the transitional effects were provided. The renewable energy system experiments in India serving to improve the local energy provision were exceptional in covering long periods of time – even over a decade (Romjin et al., 2010). Such long-term studies are important to demonstrate the fragility and evolution of experiments – in the Indian case many were halted due to intra-village conflicts over biomass resources and ownership. However,

these combinations of partial success and failures can be important for diffusion as the lessons learned can benefit similar experiments carried out subsequently in many locations (Romjin et al., 2010). This demonstrates the importance of learning in relation to substantive outcomes and also puts demands on the reporting; it is important to identify but stumbling blocks and areas of progress.

The Parkstad Limburg transition arena in 2001 (van Buuren and Loorbach, 2009) has also led to the application of the same approach elsewhere (mainly in the Netherlands and Belgium) in several reported cases during 2007-2013 (Loorbach and Rotmans, 2010; Nevens and Roorda, 2014; Wittmayer et al., 2014), i.e. broadening. The experiment to set up Carbon Neutral Municipalities Network in Finland (Heiskanen et al., 2015) has through good experiences resulted in the expansion of the network as well as plans to apply a similar model to a network of resource efficient municipalities. These experiments have been close to piloting or prototyping of an idea to develop practice. They have included substantial elements of action research and their ability to influence policies and wider regimes depends crucially on successful duplication and also use as iconic examples in policy development.

What becomes clear from the analysis is that many of the described experiments are such that, rather than upscaling, we should talk about either linking various different experiments or duplication of the successful experiments (broadening) to achieve wider system transition. In a sense this network of local level experiments could enable system transition, fitting the MLP heuristic of regime change based on the emergence of a new “dominant design”. However, successful experiments in district-level land use planning to support more eco- and energy-efficient buildings also create at least potential – if not yet realised outcomes – of systemic change based on scaling up of local planning practices through regulatory change and improved building technology with global upscaling potential.

4.4. Typology of experiments

Due to the scope of the papers, particularly many being associated with sustainability transition studies, experiments were often perceived as a way to reconfigure existing socio-technical systems on its various dimensions (socio-cultural, technological, regulative and institutional) (e.g. Berkhout et al., 2010; Bulkeley et al., 2013, 2014a; Sengers and Raven, 2014). A consequence is that they were not positivist experiments designed to provide evidence through statistical analysis, but aimed instead at proof of concepts and the initiation of learning. The activity of the experiment itself often occurred in niche spaces protected from the mainstream environment and its “selection pressure” (e.g. Brown and Vergragt, 2008; Ceschin, 2014; Farrelly and Brown, 2011). In addition, a majority were climate governance experiments in a sense of aiming to reduce greenhouse gas emissions or adapt to the effects of climate change. Some experiments were broader in problem definition and focused on “real-life problems, new ways of doing things, new ways of thinking, and new ways of relating to one another and to the world” (Wittmayer et al., 2014). In addition many experiments were associated with the literature on urban labs or urban transitions (e.g. Bulkeley et al., 2014; Evans and Karvonen, 2014).

All the reviewed experiments had emerged from a desire to contribute to concrete, broader, societal objectives rather than merely being standard feasibility studies for a particular location or context. To understand their nature one needs to go beyond the authors' descriptions of the experiments to form a more comprehensive typology (Table 3). A typology helps to clarify the field of studying experiments. The need for such clarification is underlined by our finding that 17 of the 25 papers reviewed did not use a specific definition of experiments, so what they meant by an experiment had to be deduced from the cases described.

In one end of the spectrum, there are the experiments that aim to test a particular technology or service and create a new innovation niche around it. These fit the standard conceptualisation of transition studies and can therefore be labelled as "*niche creation experiments*" (Table 3). They are well defined and easily recognisable as separate experiments that have a limited duration. In the other end of the spectrum, experiments are oriented towards larger scale problem solving or change processes typically through joint vision creation. These "*societal problem solving or change experiments*" frequently involve an element of empowering citizens and the local community to take more ownership, either through shared arrangement with the administration or as an alternative to it, sometimes associated with novel governance or institutional arrangements.

An intermediate type of experiments are those with a strategic objective to stimulate new markets or change the market conditions to favour more sustainable technologies, such as more energy efficient buildings or renewable energy technologies. The "*market creation experiments*" involve attempts to change market conditions. In one case an experiment encouraged the creation of practical examples of new buildings through consumer engagement and the expansion of an existing eco-label into the building sector.[2] In another case, the aim was merely to maximise the region's economic benefit, while it was hoped to result in some sustainability outputs, yet none were reported in the article. The fourth category that we could identify, based on the cases, are "*spatial development experiments*" that aim towards long-term spatial development with sustainability benefits. The experiment types reflect their aims but are also likely to affect their outputs, addressed next.

[2] The "Swan label" has so far been mainly used for consumer goods and small appliances http://www.nordic-ecolabel.org/criteria/product-groups/?p=3 [visited Nov 10 2015]

Table 3: A typology of experiments derived from the case study survey

Type of experiment	Spatial scale	Setting	Sector focus	Reversibility	Key actors	Number of cases in the review
Niche creation	Initially local rural/urban but with an aim to expand	Protected niche	One or two sectors	Easy	Local, individual innovators	9-10
Market creation	Regional, national or broader	Several niches or policy	One sector	Initially relatively easy, becoming difficult when size grows	Innovators, marketers, procurement specialists, policy-makers	5-6
Spatial development	Local or regional	Concrete use of space and land	Cross-sectoral	Difficult, but slow development provides opportunities for realignment	Local/regional policy makers and stakeholders	10-11
Societal problem solving and change	Local, regional or national	Policy level	Cross-sectoral	Context dependent	Policy makers, change agents and stakeholders	15

5. Discussion

5.1. Experiments and transitions

In the literature on sustainability transitions, experiments with a strong policy dimension have not been extensively reported. This view by Bos et al. (2013) is confirmed by our systematic review. Rather, the literature typically focuses on technology experiments, e.g. in renewable energy (e.g. Romijn et al., 2010), or mixed experiments which combine technology, service and policy components, for instance in an urban context (e.g. Castan Broto and Bulkeley, 2013). It is somewhat paradoxical that experiments are a core part of the transition management approach, while the analyses of empirical experiments and the criteria by which they are set up are still in their infancy (Porter et al., 2015). One reason is that TM in itself is at an experimental stage (mainly explored in the Netherlands, see e.g. Dietz et al., 2008; Kern and Howlett, 2009), and the articles reviewed portrayed more a picture of transition arenas as an experimental approach to governance rather than paying (any) attention to specific transition experiments that would emerge from the transition arenas. Clearly, when experiments are one of the key concepts in the idea of transitions, we should be more specific about the nature, characteristics and the expected outcomes of such experiments in promoting transitions. A typology of experiments is a first step in clarifying how experiments inform and contribute to transitions.

Outcomes of experiments are particularly pertinent in discussing the role of experiments in transitions. Whereas the underlying intention of transition experiments seems policy oriented in challenging existing socio-technical configurations (Bulkeley et al., 2014a), our review

identified several experiments that did not visibly challenge the existing policy and institutional framework – which in previous research has been identified as key locus for high-carbon path dependence (e.g. Unruh, 2000; Pierson, 2004). This could be due to an experimental bias; it is easier to set up and follow a technological experiment than a politically messy process. Moreover, significant policies are always difficult to change (e.g. Kivimaa and Kern, 2016). A "culture of experimentation" may lower barriers to change by introducing experiments that can be easier to accept politically due to their tentative nature and small scale (e.g. Newig et al., 2016). A critical question is, however, who initiates experiments and who is able to broaden them or scale them up to fundamentally change existing regimes. Experimenting can be used by the opposition to current regimes as way of undermining its legitimacy. It can, however, also be used as a political smoke screen, symbolically by a government in power that seek to prevent structural change through (more permanent) regime de-stabilising policies, that are politically very difficult (cf. Kivimaa and Kern, 2016). This suggests that there is a need for more in depth analysis of the politics of experimentation. This suggests that there is a need for more in depth analysis of the politics of experimentation.

Our systematic review of experiments shows that changed discourse has been the most common outcome of the experiments (Table 2). While in some cases this can be a purely rhetorical outcome (as in the case described by Evans and Karvonen, 2014), it is a key to learning and has the potential to lead to more profound changes through reframing of problems and possible solutions (e.g. Bos et al., 2013). For example, Scrase and Ockwell (2010) have found that transition to low-carbon energy systems demands a reframing of energy policy problems and solutions. Reframing in turn can act as a key entry point for further policy innovation or other types of regime-level change (Upham et al., 2014). Moreover, Berkhout et al. (2004) have argued that 'social aspirations that are becoming embedded in an institutional order typically first need to engage at the macro-level of the landscape of general opinion, legislation and so on, before they can become effective in seeding transition'.

Many experiments seemed to have resulted in more than one type of positive outcome from the perspective of climate change mitigation and adaptation (Section 4.4). However, what is crucial for transitions is how the experiments can expand to challenge the existing unsustainable, high-carbon regimes (policies) and how broadening and upscaling from experiments (cf. Grin et al., 2010) happens. While experiments may be politically less difficult, they will remain "just" experiments if they do not lead to learning and fail to generate commitment for future action.

5.2 Success of experiments

When is an experiment successful? Brown and Vergragt's (2008, p. 113) define three criterion for successful experiments as (1) a functioning, socially-embedded new configuration or technology or service, (2) the occurrence of higher order learning among the participants, and (3) a change in the interpretive frames or problem definitions of future users and the participants to the experiments. One could also argue that success should be measured in terms of actual progress towards the transition to low carbon sustainable societies/communities, but this is a tall order.

Many of the reviewed experiments provided proof in a form of piloting or prototyping that the new products or services work and that they can in principle be employed on a larger scale (for example disabled mobility in Cape Town, taxi metering system in Bangkok, photovoltaics in London and low energy housing in Ljubljana). These represent success at the level of the experiment besides the shifts in thinking and practices of the actors taking part (contextual learning through broadening, Grin et al., 2010). Showing evidence of higher order learning from a particular set of experiments and transforming regimes is much harder. Some indications for this can be obtained, if the niches that the experiments reside in have a likelihood of continued existence, even after the direct support for the experiment has ended. However, this does not mean that the broader strategic goal for low-carbon or sustainability transition would have become significantly closer. The critical process is the (rapid) broadening or scaling up of the experiment, so that one could talk about a new emerging dominant (technological, social, institutional) design challenging existing regimes and, as Grin et al. (2010) argue, a new constellation of culture, practices and structure gradually attaining higher influence and stability.

One can claim that the reviewed experiments are mostly too recent to provide evidence for such change but there are historical examples of rapid diffusion in other areas. For example the switch from land lines to mobile phones, the expansion of smart phones and the demise of light bulbs show that the time needed to progress from experimentation to full scale transition can be short. These examples have also demonstrated the necessity of political breakthroughs with public policies backing up the new solutions.

Only weak signs of broadening were detected in most of the reviewed experiments and the transition arenas were mostly activities driven by dedicated researchers rather than activities rapidly adopted by all planners or community developers. There is, thus, a clear need to develop a tradition of critical evaluation of experiments. Without it there is a risk that experiments become a political Potemkin village that hides the need to change policies to stimulate real transitions.

5.3. Implications for climate transition governance and its research

When examining the pool of experiments as a whole they represent a range between niche and regime levels. However, so far the literature on (low-carbon) transitions has not provided in-depth knowledge on the range of climate policy or governance experiments that have been carried out in real-life. There is a lack of information on the inputs, processes and configurations they entail, which makes it difficult to connect them to the wider literature on policy experiments (e.g. Heilmann, 2002). Therefore, there is a need for more empirical accounts that would examine *policy* experiments from a transition perspective; how the experiments link to more long-term outcomes regarding climate change mitigation and adaptation, and what is needed beyond and after the experiments.

We argue that a typology of experimentation may help to see more clearly the ways in which different experiments can complement one another in pursuing low-carbon or climate resilience transitions. Our categorisation presented in Section 4.4 include two types that operate

more at the niche level: *niche creation experiments* aiming to build a niche around a particular low-carbon technology or service and *market creation experiments* trying to create a market stimulating the emergence of new low-carbon niches around a given issue. With a wider regime orientation, *societal problem solving or change process experiments* frequently take a cross-sectoral approach, sometimes extending beyond climate change and environment to other sustainability issues. Lastly, *spatial development experiments* are also cross-sectoral but limited geographically to a given urban or regional context. Importantly, they also point to different governance strategies regarding experiments. For example, niche creation experiments often focus on a limited set of technologies, while market creation or societal problems solving experiments are likely to be more open to the idea of technology neutrality (cf. Azar and Sanden, 2012).

In terms of substance the reviewed experiments cover a range of issues regarding climate change mitigation and adaptation. Most focus has been given to renewable energy and energy efficiency improvements in housing. A few examples can also be found that address adaptation, for example, through water management. We did not find any studies of experiments targeting the reduction of energy demand regionally or in specific sectors such as transport (cf. Kivimaa and Virkamäki, 2014).

Our review indicates that studies of experimentation on the national level of governance are rare. This may, however, change. Examples of national climate related experimenting are emerging, for example, in Finnish transport governance. Also the European Commission that faces severe opposition against any legislative actions, favours experiment-like actions such as the Covenant of Mayors and the use of structural funds for experimenting with climate change measures. Experimentation to address climate change is clearly booming at the local level. This may be a response to the failure of international climate governance to achieve binding agreements and speedy action as reported elsewhere (e.g. Hoffmann, 2011) and the increasing importance of cities in promoting sustainability transitions (e.g. Hodson and Marvin, 2010). Particularly, local spatial planning practices allow for test districts (e.g. Holm et al., 2011), where more stringent planning requirements and novel building designs and community energy solutions can be easily tested. At the same time, not all local administrations are less rigid than national administration – in these cases, some experiments have attempted to bypass official local governance arrangements (e.g. Wittmayer et al., 2014).

To generate greater insights into the experimentalist transition governance, we suggest that fruitful areas of future research are: (1) the successes and shortcomings of climate experiments with reference to the policy frame – where is the inertia that experiments have to overcome in order to become ‘contagious’; (2) the emergence of experiment-like conditions in governance and policy; and (3) long term aggregate evaluations of experiments - what happens after the experiment and how can societies reap the benefits of an ‘experimental society’ for sustainability transitions.

6. Conclusions

Our systematic review and analysis confirmed that there is much diversity about what is meant by experiments, and despite several strands of research, there is not a coherent body of literature that links experiments to climate governance. Our search for material for this study showed also that there is a lack of academic empirical literature explicitly describing and evaluating climate governance or policy experiments, particularly from a transitions point of view. While transition arenas and spatial planning experiments have a close link to governance, they are seldom focused explicitly on climate issues. On the other hand, several sociotechnical or urban experiments are climate-related particularly through new energy solutions but only in some cases (of urban experiments) make a connection to policy. Thus, we call for further research that not only studies climate policy experiments in-depth and considers their success factors and role in low-carbon or climate-resilience transitions but, more importantly, is clear about the definitions of what constitutes an experiment, transparent about the purpose and parameters of such experiments, and provides balanced evaluations of the longer term value and outcomes of experimentation. This is a demanding but important task as experiments have found their way to the political agenda, where experiments can be used for advocacy rather than reflection and learning.

Our systemic analysis of recent articles on real-life socio-technical and policy experiments showed that the reported experiments – albeit viewed rather differently in different studies – can be grouped into four different categories: niche creation experiments focused around the creation of new technologies or services, market creation experiments aiming to build a market for more sustainable technologies and services, spatial development experiments focused on a geographically limited scale but crossing a number of sectors or issues, and societal problem solving and change process experiments based on joint visioning and action to address a given problem of a global or local scale. The different categories of experiments have resulted in various outcomes (Table 3) but there is, as yet, little evidence of major transitions resulting from a single type of experiments. This suggests that a broad range of experiments is necessary for a significant transformation towards low-carbon and climate-resilient societies, because the different types fulfil different roles in the political process towards transitions. In particular, they allow different types of policy innovation to be employed and tested on a limited scale – although only some of the scholarly work reviewed paid attention to this aspect related to experimentation.

While a broad range of different experiments is relevant to climate governance as a whole, also specific attention to climate policy experiments is needed to increase the value of the concept of *experiment* to climate policy and academic inquiry – if it means everything, it means nothing. Thus, by merging the identified four types of experiments with Tassey's (2014) definition of policy experimentation, we suggest that climate policy experiments in the context of climate governance should be defined as *deliberate field-trials of innovations that operate in a temporary space and scale, are reversible during the trial period, and are designed to challenge status quo policies and contribute to [social] learning [on how to advance climate change mitigation and/or adaptation]* (as opposed to 'pure' advocacy of a particular solution).

Our review has shown that experiments can be significant in creating both substantive and learning-related outcomes that change discourse, facilitate the emergence and diffusion of new technologies and changes in the built environment, and also change policy and institutions to some extent. The ways in which the immediate outputs and learning are sustained and contribute to transitions over time are crucial in determining the importance of experiments. This points to a need for developing and conducting in-depth ex-post evaluations of experiments – perhaps more than what is currently done. Our case review also showed that experiments, while changing some elements of socio-technical configurations of the dominant regime, can fail to make an impact in part or completely. This is in line with the broad idea of experiments as a route to new knowledge, although few, if any, of the reviewed experiments fulfil criteria of rigorous statistical design. The lack of rigour means that generalisations from the experiments have to be made with caution. At the same time the open-endedness and fuzziness of these experiments make it easier to deal with politically sensitive issues, and they can, therefore, contribute to greater policy learning than carefully controlled experiments. Their importance can lie in highlighting, for example, the difficulties and barriers to low carbon transitions and false assumptions behind the experiment, and thereby prevent flawed or unsustainable policy or governance innovations to be set on a more permanent basis.

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Appendix 1: Search string for the case study review

Source	Years of publication	Search term	No. of hits / relevant papers
Scopus (articles, social sciences)	2009-2014	"strategic experiment*"	11 / 2
Scopus (articles)	2009-2014	experiment* AND climate AND transition*	46 / 5
Scopus (articles)	2009-2014	"policy experiment*" AND climate	6 / 2
Scopus (articles)	2009-2014	experiment* AND "energy efficiency" AND transition*	11 / 1
Scopus (articles)	2009-2014	experiment* AND "renewable energy" AND transition*	6 / 1
Scopus (articles)	2009-2014	experiment* AND "mobility" AND transition*	26 / 4
Scopus (articles)	2009-2014	experiment* AND "transport" AND transition*	20 / 1
Scopus (articles)	2009-2014	"governance experiment" AND "climate policy"	0
Scopus	2009-2014	experiment* AND energy efficiency AND policy	18/0
Scopus	2009-2014	experiment* AND "low energy" AND policy	4/0
Scopus	2009-2014	experiment* AND "energy saving" AND policy	7/0
Scopus	2009-2014	experiment* AND "climate policy"	19/5
Elsewhere identified source articles	2009-2014	No search word	-/ 4

Appendix 2: Summary of the analysed experiments

Experiment case	Source articles	Background literature	Sector & focus	Type of experiment	Technological (T), social (S), policy (P) innovation	Local / national government involved	Climate objective	Country, continent	Scale
Sustainable mobility system in the suburban areas of Cape Town	Ceschin 2014	Transition studies, transition management, strategic niche management, design for sustainability	Transport	socio-technical experiment	T, S	local	no	South Africa, Africa	Local / suburban
ICT platform for metering motorcycle taxis in Bangkok	Sengers & Raven, 2014	Transition studies, process theory	Transport	technical mobility experiment	T, S	local	no	India, Asia	Local
Transition arena Parkstad Limburg	van Buuren & Loorbach 2009; Loorbach & Rotmans 2010	Transition management, governance of innovation	Regional development	vision-forming process based on transition management	S, P	local	no	Netherlands, Europe	Regional
Pilot project (experiment garden) Gouwe Wiericke West	van Buuren & Loorbach 2009	Transition management, governance of innovation	Land use planning; water management	Experiment garden	S, P	local	no	Netherlands, Europe	Local
Community arena building Rotterdam-Carnisse	Wittmayer et al. 2014	Transition studies; transition management	built environment, community development	community arena experiment based on transition management	S	national	no	Netherlands, Europe	Local / suburban
Finkenstein community arena building	Wittmayer et al. 2014	Transition studies; transition management	Community development	community arena experiment based on transition management	S	local	no	Netherlands, Europe	Local / district
Urban energy networks in London ESCO	Bulkeley et al. 2014	Transition studies, multilevel perspective, political economy	Energy, built environment	urban climate change experiment	S, P	local	yes	United Kingdom, Europe	Local

Urban energy networks in London photovoltaics	Bulkeley et al. 2014	Transition studies, multilevel perspective, political economy	Energy, built environment	urban climate change experiment	T, S, P	both	yes	United Kingdom, Europe	Local
Social housing and low carbon transitions in Ljubljana	Castán Broto 2012	Transition studies, multilevel perspective.	built environment, energy	low carbon energy for housing experiment	T, S	local	yes	Slovenia, Europe	Local
Oxford Road Corridor in Machester	Evans & Karvonen 2014	urban experiments	built environment	urban laboratory	T, S	local	no	United Kingdom, Europe	Local
Herfølge – Eco Labelling and Experimenting for Opening the Market to Standard Single Houses	Holm et al. 2011	Transition studies	built environment	construction and market experiment	T, S	local	yes	Denmark, Europe	Local / village
Stenløse Syd – District Planning with Ecorequirements	Holm et al. 2011	Transition studies	built environment	planning and building experiment	T, S, P	local	yes	Denmark, Europe	Local / district
H2-college in Herning – Passive House and Hydrogen Energy Technology	Holm et al. 2011	Transition studies	built environment	passive house experiment	T	local	yes	Denmark, Europe	Local / university
Hallingellie – Self-grown Radical Niche and Eco-village	Holm et al. 2011	Transition studies	built environment	eco-village experiment	T, S, P	local	yes	Denmark, Europe	Local / village
Roof transition - transition management for a firm	Loorbach & Rotmans 2010	transition management	built environment	transition arena	T, S	national	yes	Netherlands, Europe	National
Ghent as a transition management case	Nevens & Roorda 2014	transition management, urban transition labs	Multiple	transition management experiment	P	local	?	Belgium, Europe	Local
Eastern Jutland Region: Contested Planning Rationalities in Spatial Strategy Making	Olesen & Richardson 2012	Strategic spatial planning	Built environment	strategic planning experiment		both	no	Denmark, Europe	Regional
Greater Copenhagen Area - return to top-down state planning	Olesen & Richardson 2012	Strategic spatial planning	Built environment	strategic planning experiment	P	both	yes	Denmark, Europe	Regional
Region Zealand: Towards self-regulatory spatial strategy making	Olesen & Richardson 2012	Strategic spatial planning	Built environment	strategic planning experiment		both	no	Denmark, Europe	Regional
Uttam Urja energy service initiative	Rehman et al. 2010	Transition studies, strategic niche management	Energy	sustainability experiment	S	national/both	yes	India, Asia	Regional

A producer biomass gasification system in Hosahalli	Romjin et al. 2010	Transition studies, strategic niche management	Energy	socio-techical experiment	T, S	both	no	India, Asia	Local / village
Biogas system in Pura	Romjin et al. 2010	Transition studies, strategic niche management	Energy	socio-techical experiment	T, S	both	no	India, Asia	Local / village
Biogas system in Mavinakere	Romjin et al. 2010	Transition studies, strategic niche management	Energy	socio-techical experiment	T, S	local	no	India, Asia	Regional
Vegetable oil system in Kaggenahali	Romjin et al. 2010	Transition studies, strategic niche management	Energy	socio-techical experiment	T, S	both	no	India, Asia	Regional
Carbon neutral municipality in Mynämäki	Heiskanen et al. 2015	Strategic niche management	Several	local experiment	P	both	yes	Finland, Europe	Local
Urban water governance experiment in Cooks river catchment	Bos & Brown, 2014; Bos et al. 2013	Transition studies, socio-ecological systems, transition management	Water	governance experiment	S, P	local	no	Australia	Regional
Sydney-based governance experiment "Treading Lightly"	McGuirk et al. 2015	Urban experiments, carbon governance	Across	institutional experiment	S, P	local	yes	Australia	Regional
Insulated ceiling retrofit in Cape Town	Bulkeley, Luque-Ayala, Silver 2014	Social housing	Energy / built environment	urban experiment	T, P	local	yes	South Africa, Africa	Local
Adoption of solar water heating in social housing of Sao Paolo	Bulkeley, Luque-Ayala, Silver 2015	Social housing	Energy / built environment	urban experiment	T, S, P	local	yes	Brazil, South America	Local

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